TOPOGRAPHICAL ANALYSIS OF REINFORCEMENT PRODUCED VARIABILITY: GENERALIZATIONS ACROSS SETTINGS AND CONTINGENCIES

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This study evaluated the effects of programming a variability contingency on one object and the generalization of variability across other objects and contingencies when the defining features of the variable responses were topographical differences. A dog's interactions with five different objects were measured under both ANY (where any physical contact with the object would be reinforced on a fixed ratio schedule) and the VAR contingencies (where only the novel responses per trial would be reinforced). The ANY contingency produced stereotyped responding of behavior with all objects. When one of the dog–object interactions was changed to the VAR contingency, a marked decrease in stereotypic behavior and an increase in novel responses in the form of topographical combinations were observed across both contingencies.

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INTRODUCTION

Behavioral variability produces adaptations conducive to the survival of the organism. For example, food acquisition by predators requires variations in strategies to accommodate for the varying escape topographies of prey. Foraging strategies for both prey and predator may need to be varied when ecosystems are in flux. A particular predator/prey dynamic, driven by behavioral variability along with structural and physiological adaptability, has been one of the major selective forces in evolutionary change. A specific example of the need for variability can be seen in the recent behavior of mountain lions. At the same time that the mountain lion population has been increasing across North America, human residences have been encroaching into its habitat, decreasing its natural prey population. Compounded by habituation to humans and the availability of alternative and readily accessible sources of food (e.g., trash and animals present in the suburban environment), mountain lions have been able to vary their foraging strategies to adapt to a rapidly changing environment.

The world of professional sports provides an analogous example. Sustaining a career in professional sports requires athletes to win and entertain the public. In order to succeed in both endeavors, athletes (and their coaches) are pressured to vary their strategies to produce bigger, faster, and stronger athletes. Socioeconomic and cultural demands for increased competition and improved performance have produced variations in their diets, training regimens, and performance-enhancing drug use.

In a training context, variability can be beneficial, especially in situations in which stereotyped behavior is maladaptive. In order to begin shaping, it is helpful to have a range of topographies with which to begin the modification process.

The more topographies the practitioner can work with in the initial stages, the faster the topographies can be narrowed down to those that target individual behaviors with selective reinforcement. According to the principles of probability, the more topographies offered, the more likely it is that the trainer will encounter variations that serve as approximations of the target behavior.

Given the adaptive significance of variability, it is no surprise that the prospect of explicitly controlling it has been a vibrant area of research. Variability can be attributed to several factors, including operant conditioning, drugs (Brugger, 1997), noncontingent environmental events (Bandura, 1982), memory of past responses (Neuringer, 2002), and extinction or respondent effects (Cherot, Jones, & Neuringer, 1996). This paper concentrates on the possibility of directly reinforcing variation as a dimension of behavior.

Variability as a reinforceable dimension of behavior has been evidenced by the literature over the last 30 years (see Goetz & Neuringer, 1973; Machado, 1989, 1993, 1997; Neuringer, 1986, 1991, 1992, 1993, 2002). For example, Page and Neuringer (1985) showed that pigeons' variable responding depended on a contingency of reinforcement that required them to emit a sequence of eight left and eight right key pecks that differed from the previous 50 sequences (referred to as a Lag 50). This level of variability was produced only when required by the contingency. When pigeons were placed on a yoked VR (variable ratio) schedule that reinforced pecking independently of any variation in sequence, the pigeons responded with high stereotypy. Similarly, Miller and Neuringer (2000) reinforced variability in the behavior patterns of five adolescents with autism. The dependent variable consisted of sequences of left or right button pushes on a computer.

Under the treatment condition, only infrequently emitted sequences were reinforced. Their findings rebutted other hypotheses of that time that had contended that persons with autism were incapable of variation in behavior (Boucher, 1977).

Operant variability studies have almost exclusively researched variability of sequences in lever pressing, button pushing, or pecking as dependent variables. Notable exceptions are studies by Goetz and Baer (1973) and Pryor, Haag, and O'Reilly (1969). Goetz and Baer reinforced creative play in children by reinforcing novel constructions with wooden blocks. During variability conditions (from here on referred to as VAR), only novel constructions were reinforced, and during repetition of construction phases, only a single construction type was reinforced. The VAR conditions yielded a higher number of novel constructions than the control condition. Pryor et al.'s research with porpoises used a *novel response procedure,* a procedure that reinforced any response upon its first occurrence. They were successful in producing 16 entirely novel topographies, including breaching, porpoising, inverted swimming, tail slaps, and sideswipes.

With the exception of Pryor et al.'s study, the dimension of analysis for operant variability has not been variable motor patterns themselves, but rather the outcome of responding (e.g., lever press and key peck sequences, block buildings, and sequences of keyboard presses). In other words, the focus of analysis has not been on behavior in and of itself but on the effects of behavior. It has been assumed that if an outcome was variable, then the behavior that had produced it was equally variable. A few studies have examined variability in topography produced by mechanisms other than reinforcement. Some notable examples include a study by Antonitis (1951) tracking the variability of nose-poking responses of a rat across a 50 cm horizontal strip during an FR1 (reinforced every occurrence) and through extinction.

Similarly, Notterman (1959) studied the force variation of the lever pressing of rats. Lane and Shinkman (1963) analyzed the variance in amplitude, duration, and frequency in the per-second cycles of vocal responses of four humans and a chick during FR1, variable interval schedule (VI), and extinction. Bijou (1958) measured children's lever pressing and various off-task variable topographies such as mumbling, hitting the keys in variable ways, playing with trinkets, thumb sucking, resting heads on arms, and general increased activity.

Behavioral variability is thought to occur along a continuum from stereotypic to stochastic behavior. The onus is on the experimenters to define cohesive parameters of behavioral variability that logically fit their theoretical and experimental models. Manoel and Connolly (1995) described a dimension of variable responding that is overlooked by the majority of operant variability literature: *motor pattern variation*, or a focus on the variable behavior itself. A focus on lever press and key-peck sequences yields information on complex arrangements produced by VAR, but these responses are fairly circumscribed topographies that encompass the same muscle group recruitment. The variation in motor pattern topography from a Lag 5 (differed from the previous 5 responses before reinforcement occurs) to a Lag 50 is not nearly as variable as the Lag 50 itself. Even the novel block buildings created by children and used by Goetz and Baer (1973) appeared to consist of fairly constricted parameters of motility. Furthermore, their study did not track motor patterns but rather the block structures themselves. Neuringer, Deiss, and Olson (2000) affirmed,

> We know of no study where variable motor responses are explicitly reinforced during training. Our research suggests that concurrent reinforcement of response variations could facilitate learning of complex motor acts, and such reinforcement serves to motivate responding while at the same time provides the variable substrate from which motor skills are selected. (p. 109)

Pryor et al.'s study on porpoises stands alone in this respect; the focus in the study was on variations in motor patterns per se and not on the effects of behavior. However, of all the different organisms that have been used for operant variability studies (e.g., humans, pigeons, and rats), the muscle groups of porpoises are most lacking in independent mobility from one another. That is, if the porpoise performs a tail slap, the topography will inevitably encompass not just the tail but also the midsection and head; a change in head orientation will likewise affect tail topographies. Other than in their lateral fins, there is little muscular independence in the porpoise. Therefore, the variability results for porpoises probably do not serve as the most accurate model or analogue for organisms with more independent muscle control. However, the focus on topography itself in Pryor et al.'s study remains a relevant, important, and unique approach that warrants further study.

The development of complex topographies is a frequent subject of analysis in the field of psychophysiology. In general, the emphasis in the study of motor skill development has been on the stabilization of motor patterns. However, Manoel and Connolly (1995) described the importance of variability in motor behavior for the process of skill adaptation. Given the dynamic nature of the interaction between the organism and the environment, it is necessary to occasionally reduce variability for skill adaptability. Conversely, the organism must also be able to reorganize stabilized behavior and increase variability to meet the needs of a changing environment. The nature and extent of this adaptation depend greatly on the pressures of the environment. Manoel and Connolly argued that motor pattern variability is an essential component in the development of any biological system. Environmental constraints make the ability to behave in different gradients, ranging from variance to invariance, the very basis for the organization of topographies that make up the adaptive repertoire of the organism.

In other words, motor skills are acquired through variations of component motor patterns coming together to serve an adaptive function.

The shift in focus from behavioral effects to the topography itself has resulted in motor pattern rearrangement being considered the composition of new behaviors that can be measured as variable. In other words, motor pattern rearrangement sheds light on the processes and behaviors of which operant variability is likely to be composed. Not only can one observe variability within motor pattern rearrangement but also *contingency adduction*, the process by which component responses are initially reorganized and combined to form a new skill (Andronis, Goldiamond, & Layng, 1983). From an applied standpoint, a shift in focus on topography yields information on the scope of possible influences in a variability training procedure. That is, it presents a detailed description of the reorganization of component motor patterns that combine to form a motor skill or adaptive behavior during selective reinforcement for novel responses.

Another benefit of topographical definitions is that they can permit the performance of sensitive tests for generalization effects. The present study evaluated the generalization effects of programming a variability contingency on a dog's interaction with one object and the generalization of variability across three other objects with topographical differences as the defining features of the variable responses. This approach allowed description of the precise effects that the objects of interaction had not only on the frequency of a variety of responses but also on the particular motor pattern recruitment. When the environment was changed, generalization effects became clearly and multidimensionally evident in the topography itself.

Operant variability research typically uses *VAR* procedures to analyze levels of variation. VAR is a contingency in which variability (however it may be defined in that particular study) is reinforced. Operant variability research has also employed *ANY* contingencies, which use reinforcement schedules that are independent of sequence variations to show the levels of variable responding during contingencies that do not require variable responding. Page and Neuringer (1985) used a yoked contingency whereby reinforcement during the ANY phase was delivered independently of variation but replicated the reinforcement frequency used in the VAR phase with a percentile reinforcement schedule. Neuringer and Huntley (1991) used a VAR/ANY/VAR arrangement. As in the Page and Neuringer study, there was less variability generated during the ANY phase. Miller and Neuringer (2000) used an ANY/VAR/ANY arrangement with adolescents with autism and typically developing children and adults. This arrangement showed low variability during the first ANY phase, high variability during the VAR phase and, possibly counterintuitively, persistence of variability during the return to the ANY phase. That is, humans maintained variable responding during contingencies that did not require them to do so, immediately after experiencing the VAR contingency. No studies have investigated the effects of an ANY/VAR/ANY arrangement with nonhumans.

The rationale for an ANY/VAR/ANY arrangement is threefold. First, it offers baseline data on the level of variability present prior to the VAR reinforcement procedure. This separates the effect of the VAR procedure from previously existing variability levels in responding and hence shows a clean independent variable influence. Second, it offers information on a previously existing repertoire in the organism that may affect the variable responding itself. That is, it permits a description of the effects of motor pattern topographies and repertoires existing prior to the VAR phase on the variable response distribution.

Third, it may permit a preliminary analysis of differences between human and nonhuman organisms in their retention of variable responding during ANY contingencies.

The purpose of this study was to evaluate the topographical variability produced under the ANY and VAR contingencies across objects of interaction by a dog.

METHOD

Subject

An obedience-trained six-year-old female Border Collie (Rush) was the study subject. Topographies in her repertoire relevant to the study included nose touching on cue, retrieving, an extensive history of shaping, and the use of a clicker as a conditioned reinforcer.

Setting and Materials

The training facilities changed once during the 1.5 year-long experiment. The first experimental setting was a large room containing five chairs and large wall-length mirrors typically used to teach dog-training classes. The floors were uncarpeted but covered with rubber mats. The second training facility was a smaller and uncarpeted room containing four chairs. The trainer and dog conducted the experiments at the end of each of the rooms close to a wall. The training materials were placed approximately four feet in front of the trainer and the dog was situated between the materials and the trainer. Although able to walk freely around the room during each trial, the dog stayed in close proximity to the trainer throughout the experiment.

Five different objects that allowed for different appendages and gross motor patterns to be used were present through each of the phases: a plastic gate, a Hula Hoop®, a tin bell attached to a string, and a 0.609 x 0.609 m cube.

During the first 54 trials, a human sitting in front of the dog served as an object of interaction. The responses that were eventually produced with the human functioning as *manipulanda* became unsafe and impractical. Therefore, this experimental option was discontinued. The plastic gate was made up of three 0.609 m high links attached together to form a triangle. The Hula Hoop® was a standard hoop bought at a toy store. The tin bell was a small, two-inch-high tin bell attached to a shoe string. The 0.609 x 0.609 m cube was a carpeted ottoman with a small opening to a hollow interior. The human used as an object of interaction sat cross legged with her head facing down and her hands covering her face. The dog was familiar with the human. A traditional clicker and treat bag were used as well as Natural Balance™ dog treats chopped into 0.5 inch pellets. A sports stopwatch was used to keep time.

Measurement

The following four classifications of behaviors were measured:

1. *Repeat behaviors*. Repeat behaviors are topographies resulting in contact with the objects of interaction in a manner that had previously occurred within the current session.
2. *Novel Within Session behaviors.* Novel Within Session (Novel W/S) behaviors are topographies resulting in contact with the objects of interaction in a manner that had not yet occurred within the current session but had occurred within previous sessions.
3. *First Time behaviors.* First Time behaviors (First T/T) are topographies resulting in contact with the objects of interaction in a manner that had not occurred within the current or previous sessions.

4. *Combined First Time behaviors*. Combined First time (Combined First T/T) behaviors are topographies resulting in a combination of previously observed behaviors.

Data were scored throughout the viewing of each videotaped session and the trainer named each topography as it occurred. This procedure offered visual as well as auditory information concerning the behaviors. The videotapes were also used to determine interobserver agreement (IOA).

Examples of Topographies Measured

The criteria for reinforcement during either VAR or ANY phases were based on the types of physical contact made with the objects of interaction. For ease of measurement, the focus of the study was on gross motor patterns only. Topographies were defined by (a) the body part(s) used to make contact with the object, (b) the effect of the body part upon the object (e.g., lift or push), and (c) where the object was touched (e.g., a nose touch in the middle of the gate would be considered a different behavior than a nose touch on the bottom or top of the gate).

If a combination of behaviors (e.g., a nose touch in addition to a right-paw touch) occurred simultaneously, the combination was recorded as a different behavior from its topographical components, which would be classified as Repeat, Novel W/S, or Combined First T/T. The criterion that determined whether these behaviors were considered a single topography or two or more behaviors was their temporal proximity to each other. That is, if the behaviors occurred either simultaneously or within approximately one second of each other, then they were considered a single topography and data point.

Some topographies were exclusive to certain objects of interaction. For example, biting and lifting could only occur with the Hula Hoop® and the bell on a string.

Some behaviors used the same appendage but with a slight variation, such as a right- or left-paw kick that was similar to a paw touch except they included a retraction of the paw that sent the hula hoop behind the dog. The body parts used were the nose, both forepaws, the top of muzzle, the front teeth, and the canine teeth.

The following are the topographies observed during the experiment:

1. *Gate.* The gate topography consisted of a nose touch bottom, nose touch middle, nose touch high, muzzle tap (tapping an outer ridge of the upper part of the gate with the muzzle), right-paw touch, left-paw touch, right-paw touch high, left-paw touch high, bite, and any combination of these behaviors.
2. *Hula Hoop*®. The Hula Hoop® topography consisted of a nose touch, right-paw touch, left-paw touch, right-paw kick, left-paw kick, nip (with only the front teeth), bite, bite-lift (biting and lifting the object), and any combination of these behaviors.
3. *Bell on a string.* The bell on a string topography consisted of a nose touch, right-paw touch, left-paw touch, right-paw kick, left-paw kick, nip (with only the front teeth), bite, bite-lift (biting and lifting the object), and any combination of these behaviors.
4. *Human.* The human topography consisted of nose touch, left-paw touch, right-paw touch, left-paw kick, right-paw kick.

5. *Cube*. The cube topography consisted of a nose-touch bottom, nose-touch middle, nose-touch high, right-paw touch, left-paw touch, right-paw touch high, left-paw touch high, right-paw touch low, left-paw touch low, bite, and any combination of these behaviors.

Interobserver Agreement

All 94 sessions were captured on video and repeatedly viewed to ensure accurate recording of the numerous and rapidly changing topographical variations within each session. For example, Session 73 had a total of 21 behaviors that occurred within a one-minute time period. Two observers, both professional dog trainers and one of whom worked with the dog during the videotaped sessions, scored the data.

The following three levels of observation were maintained throughout the study:

1. The trainer called out topographies as they occurred during the session to facilitate scoring during the video observation.
2. The trainer then reviewed the video and recorded the topographies on an Excel worksheet based on what was seen and heard.
3. The observer then reviewed the video and recorded the topographies on an Excel worksheet.

The IOA measurement was derived by comparing the topographies scored by two observers who individually watched the video. Out of a total of 1,289 topographies, there was disagreement on 11 and agreement on 1,278. The IOA was calculated to be 99% between the two observers using the following exact agreement formula:

$$A_{freq} / A_{freq} + D \text{ X } 100$$

$$1{,}278/1278+11 \text{ x } 100 = 99\% \text{ IOA.}$$

General Procedures

In each session, the trainer sat in front of one of the four objects of interaction in a quiet environment. Videorecording of the session began approximately five seconds before the trial was initiated. The dog lay down on command approximately one meter away from the trainer and object of interaction. The trainer emitted a release cue; in most sessions, the word break served as a reliable cue for the dog to stand up and approach the object of interaction. The one-minute trial began as soon the release cue was given. The dog responded to the release cue by getting up and walking towards the trainer and object of interaction. No preliminary training was required for this response.

Once the trial began, the trainer's behavior consisted exclusively of pressing the clicker and delivering food by hand, avoiding any other type of contact with the dog such as praise, petting, or prompting. The only exception was the trainer's neutral tone vocalizations identifying the dog's topographies for recording purposes. The trainer waited for the response without voicing additional cues, maintaining a cross-legged sitting position and facing the dog and objects of interaction. As soon as dog made contact with the object with any part of her body, the trainer pressed the clicker, reached in the treat bag, and placed his hand in front of the dog so that the dog could take and ingest the treat within one or two seconds. The trainer would voice the topography witnessed for recording.

The following contingencies were used during the experiment:

1. *ANY contingency (baseline phase).* During this phase, the trainer clicked and treated following any type of physical contact that the dog made with one of the four objects. For example, if the dog touched the gate with her nose or her paw, then the trainer pressed the clicker and handed her a food pellet. If the dog repeated a behavior or performed a different behavior, the trainer again clicked and treated with a food pellet. The criteria to move from the baseline to the next phase (VAR contingency) was the presence of a high number of stereotypic responses and a low number of variable responses.
2. *VAR contingency*. In this phase, responses during sessions with the gate were reinforced only the first time they occurred within the one-minute long session (i.e., a Novel W/S response). Specific responses could be reinforced numerous times throughout the condition but only once within each one-minute session. During VAR phases, ANY contingencies were active for the other three objects. Interactions with the gate were reinforced according to the VAR contingency whereas interactions with the other three objects were reinforced according to the ANY contingency. The return to baseline was implemented during a positively accelerated upward trend in variable responding. A total of 11 sessions were conducted using the VAR contingency (i.e., with the gate) between sessions 27 and 68.

Experimental Design

The experiment was conducted using a reversal with a nested multielement design. The first 26 and the last 22 sessions were held exclusively under the ANY contingency and hence served as the baseline and return to baseline. During the VAR phase, the VAR contingency was active exclusively for interactions with the gate and the ANY contingency was active for each of the three remaining objects.

RESULTS

Figure 1 shows the cumulative number of Repeat, Novel-W/S, and First T/T responses across the baseline ANY phase and return to baseline ANY phase.

Baseline ANY Phase

A total of 347 measured responses were recorded over the 26 sessions of the baseline ANY phase. Of these behaviors, 300 (88%) were Repeat behaviors, 43 (11%) were Novel W/S behaviors, and 4 (1%) were First T/T behaviors. The trend for Repeat topographies was constant, consisting of an average frequency of 12 responses per session for the first 15 sessions. Around session 16, the average frequency decreased to 11 responses per session, but increased during sessions 22 to 26 to an average frequency of 14 responses per session. The frequency of responding for Novel W/S behaviors was constant at a rate of approximately 1.6 per session. The frequency of responding for First T/T behaviors began at 15 responses per session during the first 5 sessions and decreased to 0 thereafter.

VAR Phase

A total of 583 measured responses were recorded over the 45 sessions of the VAR phase. Of these behaviors, 287 (49%) were Repeat behaviors, 231 (40%) were Novel W/S behaviors, and 65 (11%) were First T/T behaviors. Three different slopes of Repeat behaviors were measured during the VAR phase. The first slope from sessions 28 to 34 showed a frequency of 15.5 Repeat responses per session. The second slope from sessions 35 to 55 showed a frequency of 5.7 Repeat responses per session. The third slope from sessions 56 to 71 showed a frequency of 2.8 responses per minute. The trend for Novel W/S was a positively accelerated growth function with an average of 5.1 responses per session.

The trend for First T/T was negative acceleration, beginning at 0.44 responses per session for sessions 27 to 35, increasing to 1.8 responses per session for sessions 36 to 69, and decreasing to 0 responses per session for the last two sessions of the VAR phase.

Return to Baseline ANY

A total of 359 measured responses were recorded over the 23 sessions of the VAR phase. Of these behaviors, 260 (72%) were Repeat behaviors, 89 (24%) were Novel W/S behaviors, and 10 (2%) were First T/T behaviors. The trends were stable for all the behaviors. The rate of response was an average of 11.3 responses per session for Repeat behaviors, 3.8 responses per session for Novel W/S behaviors, and 0.43 responses per session for First T/T behaviors.

Figure 2 shows a per object comparison of cumulative results for Repeat, Novel W/S, and First T/T across baseline (ANY), treatment and return to baseline (ANY). The tick marks represent instances in which sessions where actually occuring.

Hence, a flat line does not represent a lack of responding in the cases in which a tick mark is not present. These were instances in which there were no sessions for that object in effect.

Figure 3 shows First T/T behaviors across the ANY/VAR/ANY arrangement per object of interaction. As the only object under the VAR contingency, the gate had a total of 24 first-time topographies throughout the experiment. The hoop, having a contingency that did not require variability (ANY), had a total of 36 responses, the highest number of First T/T behaviors. The bell on a string had 16 First T/T behaviors, the human had two First T/T behaviors, and the cube had three First T/T behaviors.

Figure. 4 is a topographic analysis of the first- time responses across all three experimental phases.

The data points consist of First Time Topographies that fit into two categories; Uncombined First Time Topographies, and First Time Topographies Combined composed of previously seen behaviors recruited into one behavior. The behaviors are labeled and abbreviated ion the left hand column (the definitions for each abbreviation are shown below the graph). Uncombined First T/T are presented as single dots on the graph. The First T/T Combined are shown in three different colors:; black is the first behavior seen in the combination, gray the second, and white the last behavior in the topographical sequence. The sequences are read down the columns. The first 10 data points are First T/T that happened independently of other behaviors. For example, there was a single nose touch in the middle of the gate, a single nose touch on the bottom of the gate, a left- paw touch and so forth. The eleventh First T/T, however, combined two previously measured behaviors; bite + right-paw kick. There were two more First T/T that were uncombined; The 12^{th} First T/T and the 14^{th} First T/T. After that, there are only combined responses making up First T/T s until the 51^{st} response.

The 52nd, 53rd , and 63rd responses are also Uncombined First T/T. The data show that 16 out of 81 of all First T/T were Uncombined responses. The other 64 First T/T were produced from the rearrangements of component behaviors from the existing repertoire. In other words, 80% of First Time Topographies were actually Combined First Time Topographies.

DISCUSSION

During the baseline ANY phase, a high level (88% of measured responses) of Repeat or stereotyped responding was observed. The Novel W/S and First T/T responses constituted only 11% and 1% of the total, respectively. During the implementation of the VAR contingency, variable responses increased to 40% Novel W/S and 11% First T/T responses. Repeat responses during the VAR contingency decreased to an average of 49% of total responses. When the contingencies were reversed to ANY, a prompt decrease in variable responding occurred. Within two sessions of the ANY contingency with the gate, Novel W/S responses decreased to 24% of total responses, First T/T responses decreased to an average of 2% of total responses, and Repeat responses returned to near baseline percentages, increasing to 72% of total responses.

The number of variable responses varied by the object of interaction. The gate produced 24 First T/T responses, the Hula Hoop® 36 First T/T responses, the bell on a string 16 First T/T responses, the human two First T/T responses, and the cube three First T/T responses. Interestingly, the object of interaction that showed the highest degree of variability was the Hula Hoop® even though it was under the ANY contingency during the entire experiment. The topographical analysis showed that 12 uncombined novel responses and 56 combinations of responses occurred during the VAR contingency.

The ANY/VAR/ANY arrangement revealed the clear effects of the independent variables and their reversals across the four objects of interaction. The baseline ANY showed relatively low levels of variability and thus provided an appropriate point from which to evaluate the effects of the VAR contingency. The VAR phase produced a substantial increase in variability with the object of interaction for which that contingency was in effect, which generalized across other objects under the ANY contingency. Variable responding decreased across objects in the second ANY phase, supporting the effectiveness of the reinforcement procedure in generating variability.

Page and Neuringer (1985) differentiated between variability produced by extinction and reinforcement in a study that used the yoked-control phase. Neuringer (2002) explained the results of the experiment:

> Each bird's own sequence of reinforcements and timeouts in VAR was therefore replicated in Yoke. If short-term extinction, or withholding of reinforcement, was responsible [for the variability in VAR], then variability should be equal in the VAR and in the Yoke phases. That was not the result: Variability was significantly higher in VAR than in Yoke, a finding that has been confirmed many times. (p. 676)

Page and Neuringer (1985) attributed the stereotypic responding during the yoked-control phase to possibly "a function of minimizing energy expenditure (it takes more energy to alternate keys than to respond on a single key) and adventitious reinforcement of superstitious patterns" (p. 445). Yoke controls were not practical for the present study. The present study aimed to prove a more natural ecology than that of an experimental chamber in order to simulate a real-world therapeutic scenario. The reinforcers were planned and delivered by a human trainer whose fallible memory would prevent the precise delivery of Lag 50 and percentile reinforcement and time-out schedules.

In other words, the reinforcers were not programmed on a computer as is done in the majority of operant-variability research. In the absence of experimental controls, it is possible that some extinction effects played a part in the generation of variability. However, the highest levels of variability were produced during interaction with the Hula Hoop®. The contingency during that phase was ANY; hence, extinction could not have been responsible for the variability generated during those sessions of high reinforcement. These results suggest that the increase in variability was at least partially directly generated by the reinforcement procedure.

As previously mentioned, the results showed that although variable responding generalized across the four objects in varying degrees, it was not maintained during the final phase. Although the results showed that the reinforcement procedure increased the number of variable responses, they also—paradoxically—raise questions about operant classes and variability. If variability is an operant class, then why did the variability levels reverse during the return to the baseline ANY contingency? If variability is indeed an operant, then it is likely that the ANY phase would have maintained the levels of variability seen during VAR. Part of what characterizes an operant class is its modifiability by the reinforcement of its members. Since any response was reinforced during the ANY phase and the results show some variability being reinforced during VAR - therefore, we should have seen the maintenance of the variability operant class in the reversal to baseline at similar levels as VAR. Instead we saw a rapid decline in variable responding.

One may argue that there is a higher response cost (effort) for varying than for repeating, and this is why a decrease in variable responding during the second ANY phase was observed. However, the generalization of variability across the Hula Hoop® (showing the highest level of variability overall, refutes this possibility.

If response cost prevented higher levels of variability during the reversal, then response cost should have prevented the higher levels of variability shown during the hoop interactions in the ANY contingency as well.

Furthermore, if we contend that variability as an operant is evidenced through the reversals, should we then commit to classifying stereotypy as an operant class for the same reason? One of the key features of an operant class is that it can be directly controlled by reinforcement. Hence, Neuringer and Huntley (1991) and Page and Neuringer (1985) used reversal procedures to examine variability as an operant.

Their studies showed high levels of variability when variable responses were reinforced and low levels when they were not. Conversely, we could interpret the results of the present study as supportive of stereotypy as an operant because they showed high baseline levels of stereotypy when reinforced during the baseline ANY phase, low levels when variability was reinforced in the VAR phase, and a return to high levels during the reversal to the ANY phase. If a different set of criteria were applied to stereotypic responding, then an answer should be offered as to why this may be the case.

Ultimately, this is a theoretical issue that lies beyond the scope of this study but warrants further investigation using an ANY/VAR/ANY arrangements and topographical analyses. It is possible that the confusion arises when certain ontological characteristics are incorrectly attributed to variability. Variability exists exclusively as a description and/or measurement of a response sequence. It is context specific and subjectively defined; what is variable in one context may not be so in another. To say that variability is an operant is to say that subjectively defined abstractions are reinforceable.

A more parsimonious approach would focus instead on the concrete particulars that make up an operant class and not on the description of the relationship among its members. Therefore, a topographical analysis of variability may further our understanding of the phenomenon and its related issues by showing in detail precisely what gets reinforced during VAR procedures. The locus of analysis should be on objective, particular members and not on their sequential relationship.

The ANY/VAR/ANY arrangement with a topographical focus offers a description of variability in behavioral phenomena produced by reinforcement procedures. The precise behavioral makeup and substrate of the variable response becomes clearly multidimensional when the focus is on topography. Goetz and Baer (1973) stated, “Creativity could have its greatest meaning as a description of an individual’s behavior” (p. 216). In this study, *creativity* was synonymous with *variable*. This statement raises an alternative and advantageous dimension of analysis for variable responding, namely topography and motor pattern variability.

An analysis of operant variability with topography as the dependent variable could produce information in yet unexplored areas, particularly regarding the precise arrangement of the motor patterns themselves during the phenomenon defined as operant variability. It could show precisely what the organism does during VAR procedures. The baseline ANY contingency described the behaviors emitted by the dog prior to the variability contingency—the same behaviors used to create the novel combinations during the VAR contingency. Layng, Twyman, and Stikeleather (2004) explained,

> The actual moment of recruitment (of a repertoire) established under one set of conditions by an entirely different set of conditions … was given the name “contingency adduction"… The word “recruitment” is used to distinguish contingency adduction from shaping by successive approximations.

> That is, the skills come “pre-shaped,” and are selected or recruited by a different contingency than the contingencies responsible for the initial shaping. (p. 99)

The high levels of combined topographies that made up the variable responses suggest a strong correlation between contingency adduction and VAR procedures as done in the present study. When a VAR contingency was programmed, variability was produced, but the overwhelming majority of the variability was in the form of combined topographies. The results raise the possibility that VAR procedures may instead be topography combination procedures. During VAR phases, a variety of behavioral components are reinforced. The farther along that the VAR procedures progress, the larger the repertoire becomes, offering more possibilities for topographical combinations. These behavioral components could be comprised of multiple topographical dimensions, including variations of speed, strength, and motor pattern recruitment. The behavioral permutations are such that it becomes highly probable to vary. It is worth considering that VAR procedures may produce large repertoires of weakly conditioned, interchangeable topographies. During reversals, some of these behaviors become selected through a more robust reinforcement schedule, decreasing variability. Variability may be a byproduct of topographical combinations being reinforced rather than topographical combinations being a byproduct of variability reinforcement. The motor patterns used in lever pressing and pecking may be too circumscribed to measure this possibility. This shows further support for a topographical analysis of variable responding for variability analyses.

Layng et al. (2004) were successful in producing contingency adduction with the use of both oddity from sample procedures and combined-stimulus procedures with children. In their study, the oddity from sample procedure made reinforcement contingent on the student choosing the comparison stimulus that was different from the previously learned sample stimulus.

The sample stimulus was then used for the selection of a different contingency. In the combined stimulus procedure, two different behaviors were taught separately and then, through a combination of the two discriminative stimuli, they produced and reinforced the blended behaviors and hence selected the new response.

The present study's ANY/VAR/ANY design offered an additional approach for the production of contingency adductions. During ANY contingencies, the selection of component behaviors (e.g. nose touch, paw touch, and bite) was observed. During VAR contingencies, a recruitment of previously taught responses that were selected through reinforcement (e.g., nose touch and right-paw touch or left-paw touch and bite) was observed.

This study's generation of multiple topographies resulted in a high combination of behaviors that in turn were selected by reinforcement. If the therapeutic objective were to produce numerous variations in the contingency adductions, then the ANY/VAR/ANY contingency would likely be an effective starting point.

The limitations of this study deal with the difficulty in replicating operant variability studies. The procedural implications of percentage reinforcement and time-out schedules such as those used in Page and Neuringer's (1985) study are challenging to apply during trials run by a human researcher. The naturalistic environment may speak more to the demands of the applied setting; however, it also allows greater room for confounds. For example, the clicker and reinforcer delivery may have interrupted response chains and hence affected the results. One possible method of preventing this confound is changing the criteria for reinforcement. Instead of stipulating contact with the object as the sole criterion, a head turn toward the trainer after contact with the object may more accurately indicate the termination of the response.

An alternative design could measure motor pattern variations and manage reinforcement schedules utilizing video and software that allow for multidimensional analyses and control, such as those used in motion analysis research and biomechanics. This was not an option for the present study due to financial constraints.

Another limitation of the study regards the methodology used to measure the responses in relation to the IOA. In order to decrease the likelihood of error during measurement, the handler voiced the topographies as they occurred. If a topography was blocked or otherwise not visible in the video, the observer would have heard the handler call it out in the audio playback. However, it is possible that this could have resulted in observer bias. One manner of preventing observer bias may be to use more than one camera rather than verbal prompts to ensure that no behaviors will go unobserved.

This study indicated the need for more research on topographical variability gradients and the generalization of variability across environments. When variability is controlled through reinforcement procedures, it would further the analysis to determine the precise type of variability. In this study, the VAR procedure consisted of reinforcing the Novel W/S contingency. However, there was a different type of motor pattern sequence being emitted with that same contingency, namely the First T/T contingency. On the continuum from stochastic to stereotypic, the First T/T contingencies show the highest degree of variability. Clearly, the First T/T contingencies were byproducts of the reinforcement of the Novel W/S contingencies. Further research on the different levels of variability generated by reinforcement procedures may help not only increase understanding of the phenomenon but also aid in the systematization of the procedures.

This study also indicated the need for further research regarding reinforced variability generalizing across environments. This study analyzed variable responding across five different objects of interaction. There are theoretical and applied implications regarding the role of the environment in which the variable responding takes place. It would behoove the experimenter or therapist to carefully consider the object, environment, or context in which the variability is reinforced and expected to happen. Naturally, physiology is sensitive to the physical structures with which it interacts. A dog may be able to pick up an object with her mouth, but probably not with her paw, or at least not with the same degree of facility. The physical and structural limitations of the organism affect the levels of variability. This fact goes to the crux of the generalizability of VAR procedures and hence, yet again, stresses the importance of having a topographical focus when analyzing operant variability.

Skinner (1938) wrote,

> Behavior is what an organism is doing—or more accurately what it is observed by another organism to be doing…. By behavior, then, I mean simply the movement of an organism or of its parts in a frame of reference provided by the organism itself or by various external objects or fields of force. (p. 6)

Practitioners in applied fields know that only focusing on results and ignoring behavior may produce undesirable responding; results and the behaviors leading to them are not the same thing. There may be a wide gamut of behaviors, from desirable to undesirable, that lead to the same result. Similarly, an experimental focus on only the effects and not the behaviors per se could miss layers of information. Sometimes the option to focus on behavior instead of its effects is not possible or is too impractical to achieve. However, in the case of variability, an area of great relevance to the applied field (e.g., contingency adduction, repertoire diversification, shaping, instructional design, and developing creativity), it may be beneficial to focus on precisely what the organism is doing.

Fig. 1

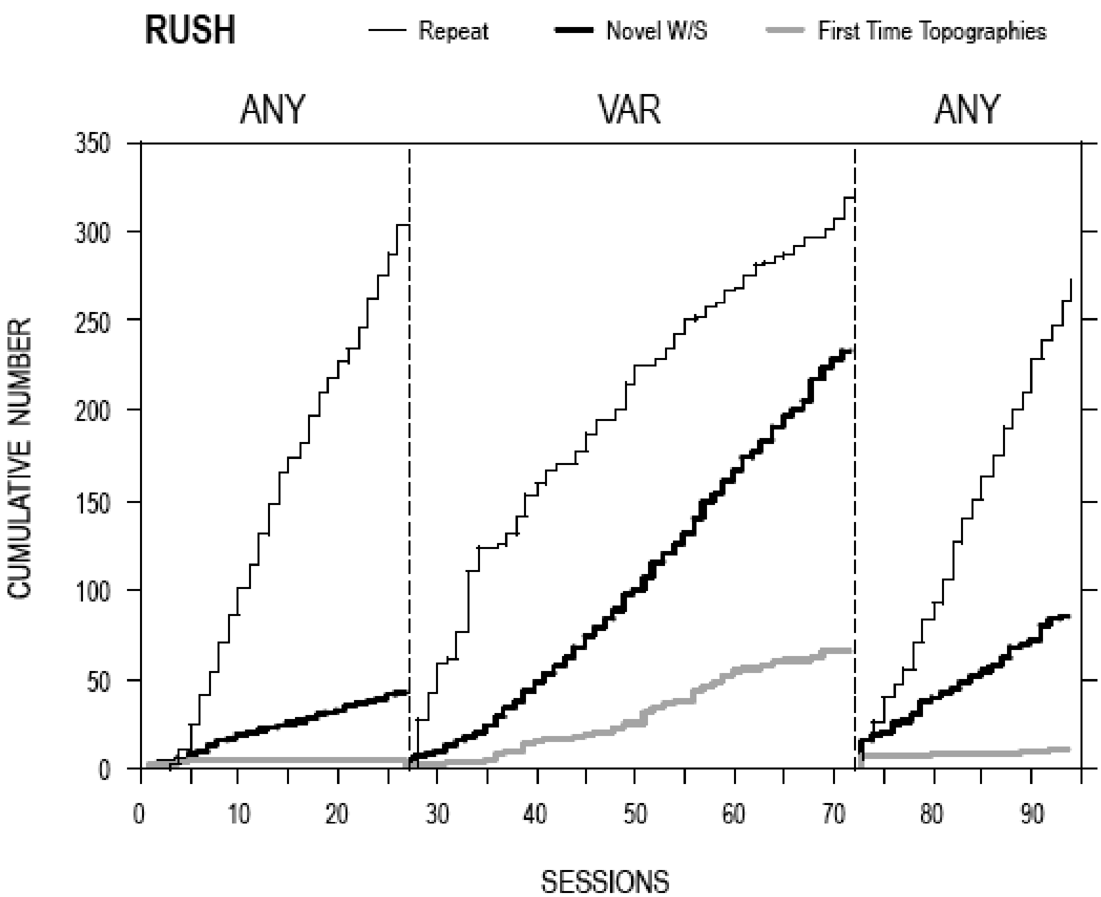
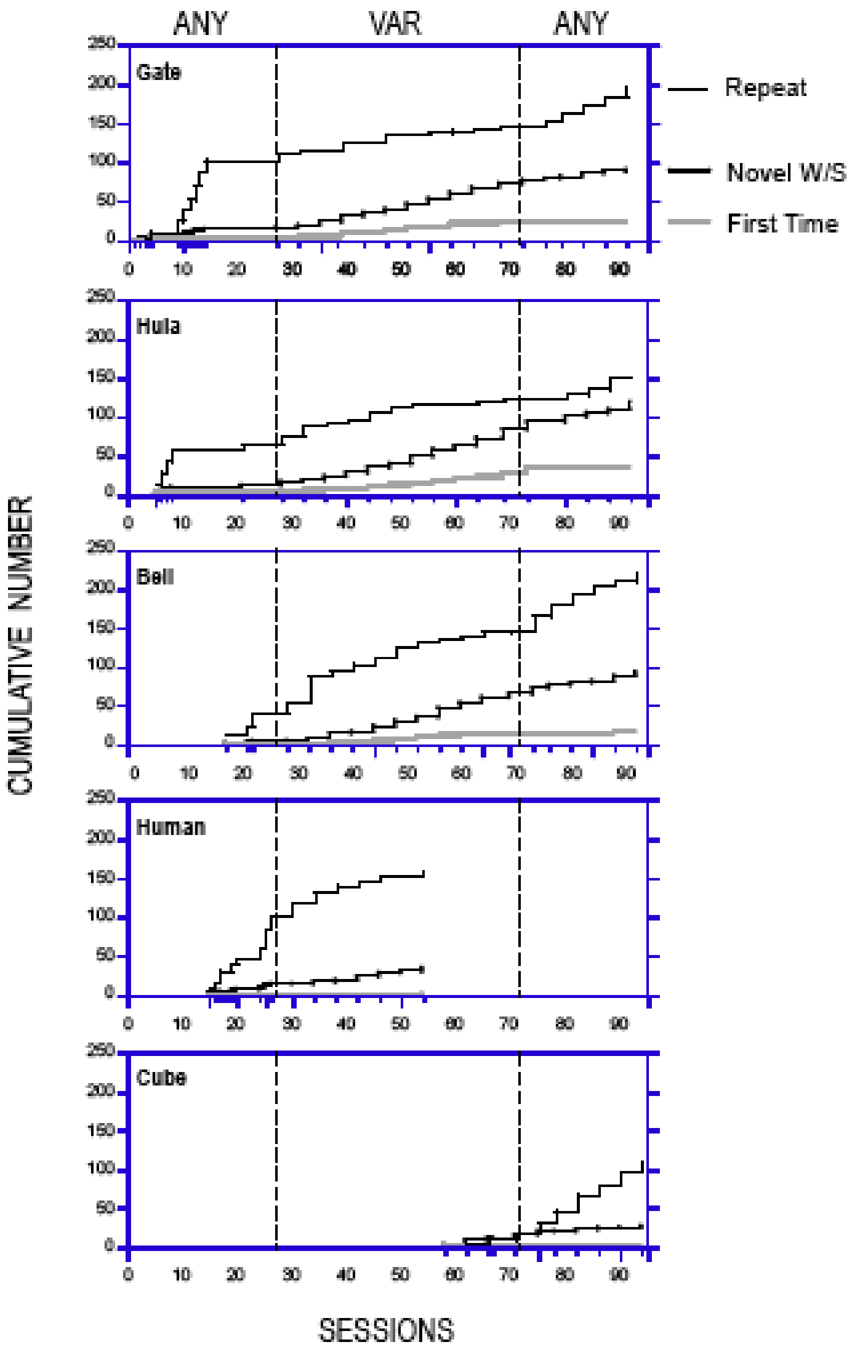

RUSH
Repeat
Novel W/S
First Time Topographies
ANY
VAR
ANY
CUMULATIVE NUMBER
0
50
100
150
200
250
300
350
0
10
20
30
40
50
60
70
80
90
SESSIONS

Fig. 2



ANY
VAR
ANY
Gate
Hula
Bell
Human
Cube
Repeat
Novel W/S
First Time
CUMULATIVE NUMBER
SESSIONS
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80
90

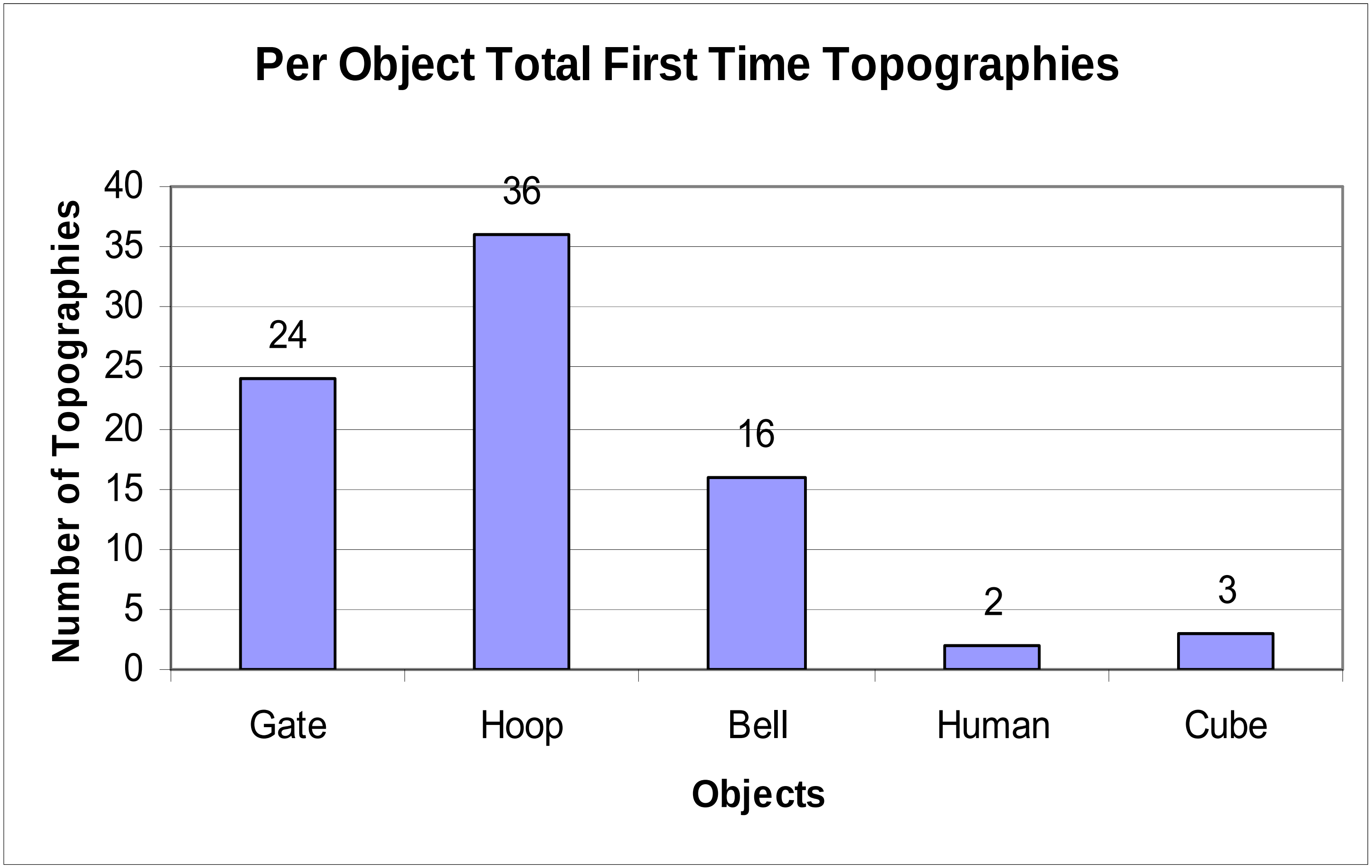

Per Object Total First Time Topographies
Number of Topographies
40
35
30
25
20
15
10
5
0
24
36
16
2
3
Gate
Hoop
Bell
Human
Cube
Objects

Fig. 3

Topographic Analysis of First Time Topographies

●= Uncombined First Time Topography

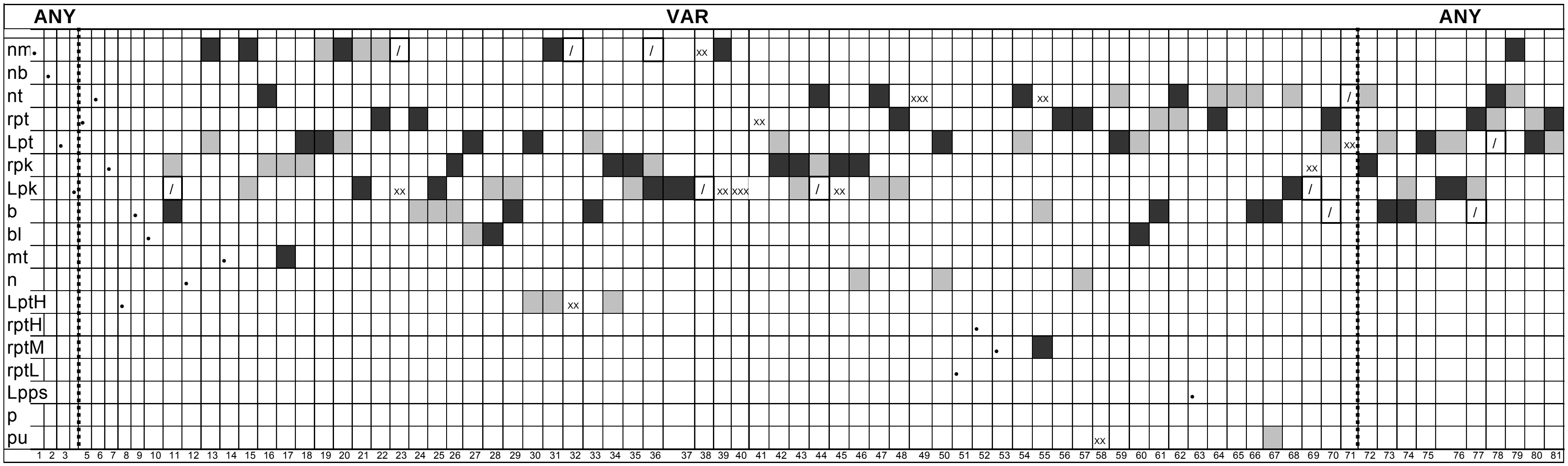
Combined First Time Topographies in Sequence

First behavior in combined sequence

Second behavior in combined sequence

/ Third behavior in combined sequence

XX=First Time Topography made up of repeated single behavior



Consecutive Topographies fig. 4

nm=nouse touch middle
nb=nose touch bottom
nt=nose touch top
right paw touch
Lpt=left paw touch
rpk=right paw kick
Lpk=left paw kick

n=nip
LptH=left paw touch high
rptH=right paw touch high
rptM=right paw touch middle
Lpps=left paw push
pu=push both paws
p=pull with mouth

b=bite
bl=bite lift
mt=muzzle tap

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